Life histories of two stoneflies (Plecoptera: Gripopterygidae) in two streams on the West Coast, New Zealand

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Abstract

Life histories of the gripopterygid stoneflies *Nesoperla fulvescens* and *Taraperla howesi* were investigated at two sites on the West Coast of the South Island. In both species nymphs grew throughout winter and emerged in spring. Middle and late instar nymphs of *N. fulvescens* were terrestrial and inhabited the dry, stony floodplain well away from the river channel; early instars were not found. Nymphs of *T. howesi* were found in an acidic, first order stream subject to fluctuating discharge and periods of drought. Its early instars were aquatic but larger nymphs occurred mainly on stones above the water at the side of the stream. By reducing the dependence of nymphs on (unpredictable) aquatic habitat, selection for life history flexibility is hypothesised to have been weaker than in fully aquatic species, enabling evolution of more strongly synchronised nymphal growth and hence the potential to maximise mating success.

Key words: Plecoptera – stoneflies – life histories – growth synchrony - terrestrial nymphs - New Zealand.

Introduction

The New Zealand stonefly family Gripopterygidae contains 73 described species in 12 genera (McLellan 2006, 2008; Gray 2009). However, the life histories, including nymphal development patterns, of only five species have been investigated. *Zelandoperla decorata* Tillyard and *Acroperla trivacuata* (Tillyard) were studied in a forest stream near Auckland in the north of the North Island (Winterbourn 1966), and nymphal development of *Zelandobius confusus* (Hare) was described from Cass in the central South Island mountains (Winterbourn 1978). Cowie (1980) documented the life histories of *Zelandoperla agnetis* McLellan, *Zelandobius confusus* and *Zelandobius unicolor* Tillyard at several sites on Devils Creek, near Reefton on the West Coast of the South Island.

The life histories of a number of common New Zealand stream insects, notably mayflies and caddisflies, are aseasonal or poorly synchronised and can have flight periods as long as 10-12 months in both the North and South Islands (Ward *et al.* 1996; Winterbourn & Crowe 2001; Smith et al. 2002), Adults of the notonemourid stonefly *Spaniocerca zelandica* Tillyard were found in 10 months at Reefton and Cass and the wide range of different sized nymphs present each month made the growth of cohorts impossible to follow (Cowie 1980; Winterbourn 2005). Similarly, *A. trivacuata*, the two *Zelandoperla* species and the two *Zelandobius* species found at Reefton had poorly synchronised life histories with flight periods of 8-11 months. In contrast, nymphal development of *Zelandobius confusus* was moderately well synchronised at Cass and adults were present in only four months.

An unusual aspect of gripopterygid nymphal ecology in New Zealand is the tendency of species to be partially or wholly terrestrial rather than fully aquatic (McLellan 1993; Winterbourn & Ryan 1994). Thus, late-instar nymphs of *A. trivacuata* move to the river margins and live on land close to the water's edge, whereas nymphs of *Nesoperla fulvescens* (Hare) inhabit the gravel floodplains of rivers, which are inundated by river water only during floods. The most extreme degree of terrestrialism is exhibited by species of *Vesicaperla, Apteryoperla* and *Holcoperla*, which have terrestrial nymphs that inhabit alpine and sub-alpine tussock grasslands (McLellan 1993).

The aim of this paper is to document the life histories of two gripopterygid species with variably terrestrial nymphal stages on the West Coast of the South Island. For one species (*Taraperla howesi* (Tillyard)) the life history was determined from by sampling at 1-2 monthly intervals in 1990-91, whereas opportunistic sampling at irregular intervals in eight years was used to decipher the life cycle of *Nesoperla fulvescens*.

Methods

Study areas

The life history of *Taraperla howesi* was studied in a first order tributary of the Waimangaroa River at Coalbrookdale near Burnetts Face on the Denniston plateau (41° 45.918´S, 171° 48.368´E), whereas *Nesoperla fulvescens* was investigated at a site on the Inangahua River south of Reefton (42° 9.353´S, 171° 54.821´E).

The tributary at Coalbrookdale was west of Mt William at an altitude of 620 m a.s.l. in an area of historical and contemporary coal mining. Hard quartzose sandstones predominated (Norton 1997) and weathered materials provided an acidic and infertile basis for the tussock, heath and scrub vegetation in the vicinity of the study site (Figure 1). The stream had a width of about 1 metre, a predominantly sandy bed and shattered rocks in the lower banks. Flow was highly variable (but unmeasured) because of the intense and frequent rainfall events that characterise the plateau.

On some visits to the stream, conductivity (Hanna HI 8333 meter) and temperature (thermister thermometer) were measured. Cool, filtered (0.45 µm) water samples were returned to the laboratory for measurement of pH (Metrohm Herisau E512 meter) and absorbance at 360 nm (Pye Unicam SOP 1800 spectrophotometer). Stream water was acidic (pH 4.1 ± SD 0.5, n = 7) with low conductivity ($21 \mu S_{25}\ cm^{-1}$ on 4 dates). At base flow, stream water was light brown (Abs_{360} 0.06 ± SD 0.02, n = 5) indicating a dissolved organic carbon concentration of about 5.5 mg l^{-1} (Collier 1987). Spot water temperatures taken in winter (June) and late spring (November) were 4.0°C and 9.4°C, respectively.

The Inangahua is a major tributary of the Buller River. It flows through beech

Figure 1. The headwater tributary flowing out of dense scrub below the study site at Coalbrookdale (photo Mark Ledger).

Figure 2. Study site on the Inangahua River showing habitat of *Nesoperla fulvescens* (photo Michael Winterbourn).

forest (*Nothofagus* spp.) in its upper reaches and some pastoral farming and coal mining occur in the catchment above the study area at 250 m a.s.l. At this point the river has a gradient of < 1% and the broad stony river bed narrows to about 40 m. Surface water was confined to a channel 10-20 m wide at base flow, but after heavy rainfall fast-flowing water could cover the entire bed. Acidic brown-water tributaries are common in the headwaters of the Inangahua and water in the main stem is usually light brown. Winterbourn et al. (2000) reported a conductivity of 28 μS_{25} cm^{-1} and a pH of 5.7 for the river above the study site. Nymphs of *N. fulvescens* were found mainly beneath cobbles and boulders well away from the main channel (Figure 2). Mud, dead leaves and fine detritus were trapped in this habitat and in some months coal dust originating from a mining operation upstream was present. The upper surfaces of some of the more stable boulders were encrusted with lichens. Late morning temperature in November 1995 when adults and nymphs were present was 26-29°C in the sun, 18°C in the shade, but much cooler (11-12°C) at the surface of fine sediments beneath cobbles where most nymphs were found.

Sampling

Sampling at both sites was non-quantitative, the aim being to obtain sufficiently large collections of insects to measure. At Coalbrookdale, samples were collected on seven occasions at 28-50 day intervals in 1990-91. Collections of *T. howesi* nymphs were obtained with a triangular net (0.2 mm mesh) by kick sampling and brushing the surfaces of stones in all habitat types present in an approximately 20 m long reach. Stones above the water at the side of the stream were also turned over and nymphs collected with forceps. At the Inangahua River site nymphs of *N. fulvescens* were terrestrial and were collected with forceps from beneath stones in the dry river bed, especially near the true right bank where they were most abundant. Adults present on the tops and bottoms of stones were collected in the same way. Seventeen collections were made between 1992 and 1999 in five calendar months (May, June, July, September, October). Searches were also made in November 1995 and 1997, and December 1994. No collections were made from January-April.

To determine the distribution of *N. fulvescens* nymphs and adults on the bed of the Inangahua River, quantitative sampling was undertaken on three occasions (October 1997, September 1998, July 1999). A transect was run at right angles to the river channel from the true right margin of the dry river bed (demarcated by a steep bank) to the water. Quadrats (0.25 m^2) delineated by a wire frame were searched at 0.5 m intervals until the water was reached. One or two people searched each quadrat by turning over and removing all stones from the frame and recording the number of nymphs and adults seen. Some stoneflies were collected to verify identification. In the laboratory, maximum head width of all nymphs and adults was measured at x25 magnification; the presence of final instar nymphs and the gender of adults were recorded.

Results

Life cycle of Taraperla howesi

Head width measurements indicated that *T. howesi* had a univoltine life cycle with well synchronised nymphal growth throughout the year (Figure 3). Final instar nymphs were present in October along with small nymphs of a new generation. The only adult collected was a female taken on the surface of a pool in October. The co-occurrence of final instar nymphs, an adult, and small nymphs suggests that development of eggs is rapid. All early instar nymphs were found in pools, whereas all final instars were out of the water amongst damp rocks. Medium sized nymphs were collected from both pools and damp stones alongside the stream.

Life cycle of Nesoperla fulvescens

A composite life history was constructed for *N. fulvescens* (Figure 4) based on collections and observations made at the study site on 17 occasions between October 1992 and September 1999.

Nymphs were found from May to October, grew through winter, and exhibited a high degree of synchrony in growth as indicated by the narrow range of nymphal size classes present in any one month. Thus, the average coefficient of variation of nymphal head width for 12 sampling occasions was only 9.2% (range 5.7-13.7%). With the exception of one penultimate instar nymph, all nymphs taken in September and October collections were final instars. Adults were found in October of 5 years and once in September; no adults (or nymphs) were seen in November and December searches. Head widths of females were significantly larger than those of males (1.54 ± SD 0.05 mm, n =18 c.f. 1.33 ± SD 0.08 mm, n = 24).

Distribution of Nesoperla fulvescens

The transect from the upper bank to the edge of the river channel was 27 m long in July and October but only 13 m

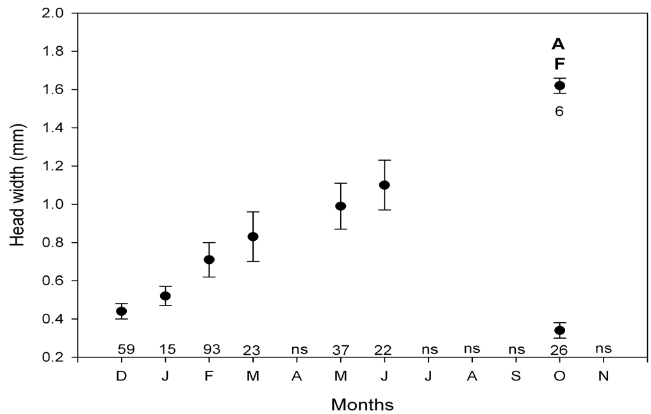

Figure 3. Temporal changes in mean head width (± 1SD) of *Taraperla howesi* nymphs in a headwater tributary at Coalbrookdale in 1990-91. F = presence of final instar nymphs; A = presence of adults. Values above x-axis = number of nymphs measured; ns = no sample.

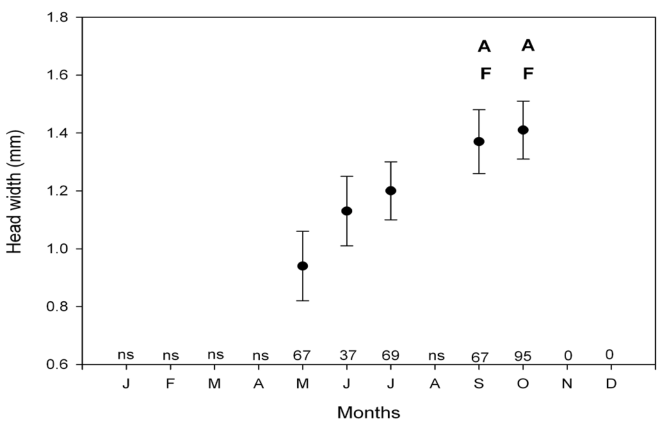

Figure 4. Temporal changes in mean head width (± 1SD) of *Nesoperla fulvescens* nymphs in the Inangahua River bed. The life history is a composite one derived from measurements made on 17 occasions between 1992 and 1999. Graphical conventions as in Figure 3 and 0 = searched for but not found.

in September when river discharge was higher and the flow channel wider. In October water was first seen under stones 11.5 m from the top of the transect and some surface water was present at the 18 m mark. In July the population comprised middle-sized larvae with minor wing-pad development, whereas in September and October all larvae were final instars and adults were also present.

In all three months larvae were confined to a 9 m long band at the top of the transect (i.e., distant from the water) (Figure 5). Final instar exuviae counted in October were also found in the upper part of the transect indicating that adults had not moved far from their emergence sites.

Discussion

Information on the life cycles of *Nesoperla fulvescens* and *Taraperla howesi* was obtained through opportunistic sampling of two separate streams on the West Coast of the South Island. Although not all calendar months were included in the study, results indicated that both species had synchronised nymphal

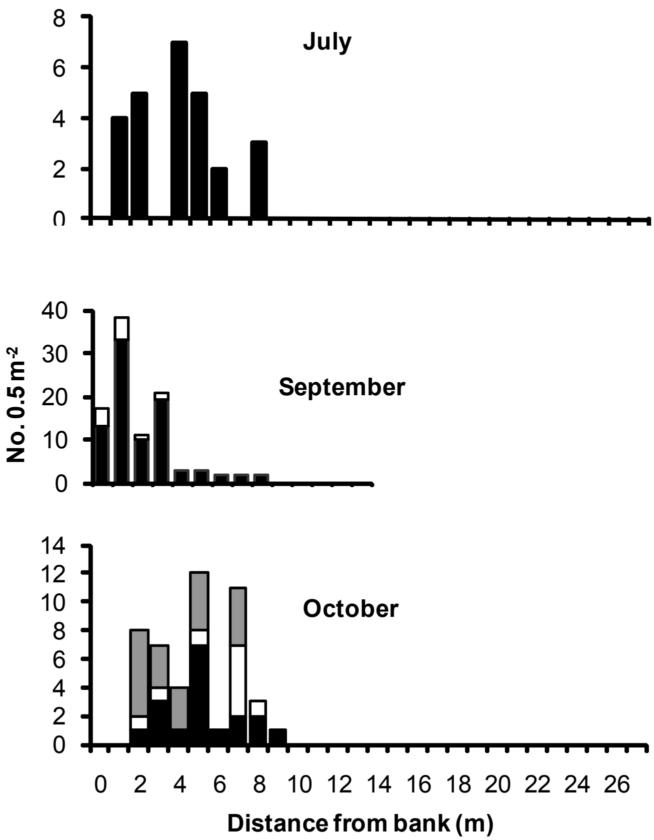

Figure 5. Numbers of *Nesoperla fulvescens* nymphs (black bars), adults (white bars) and final instar exuviae (grey bars) found on transects from the true right bank to the wetted channel of the Inangahua River in July 1999, September 1998 and October 1997. The length of each x-axis shows the distance from the riverbank to the flow channel.

growth culminating in spring emergence. Although no previous studies have dealt specifically with the life cycles of either species, spring emergence is consistent with collection records of adults elsewhere in the South Island including the West Coast. Thus, all adults of *N. fulvescens* were collected in September (McLellan 1965) and those of *T. howesi* in November and December, except for two males at 1300-1600 m in early January (McLellan (1998). McLellan (1998) also noted that as at Coalbrookdale, most early instar nymphs were found in pools with a substratum of sand and silt; however, he made no comment on the habitats of larger nymphs.

Synchrony of adult emergence and possession of a short adult flight period, as seen in *N. fulvescens*, is normally assumed to increase the probability that individuals will find mates and enhance the probability of successful reproduction (Jackson 1988). However, the occurrence of strongly synchronised nymphal growth culminating in a short period of adult activity contrasts with the life history flexibility seen in many other New Zealand stream insects including stoneflies (see Introduction). Such flexibility has been variously hypothesised to be an adaptation to the mild New Zealand climate, unpredictability of river environments with respect to flow including flood and drought events, year round availability of larval food, and the evolutionary consequence of exposure to wide climatic fluctuations over a long period of geological time (see Scarsbrook 2000).

In the study area on the West Coast *Zelandoperla agnetis* and two species of *Zelandobius* had aquatic nymphs with weakly synchronised development and extended adult flight periods that contrasted with those of *N. fulvescens* and *T. howesi* despite being exposed to a similar climate and temperature regime. It is tempting to suggest that the synchronised nature of the latter two species' life histories is associated with the moderate-high degree of terrestrialism exhibited by their nymphs. In the case of *T. howesi* the headwater larval habitat studied was susceptible to high flows and extended periods of drought that at times reduced aquatic habitat to small isolated pools. However, because older nymphs are semi-terrestrial they can probably escape some of the detrimental effects of high flows and a dry stream bed. *N. fulvescens* has evolved an even more fully terrestrial nymph, clearly demonstrated by its distribution close to the banks enclosing the floodplain and well away from the water channel, except during flood flows. By reducing the dependence of nymphs on (unpredictable) aquatic habitat, selection for life history flexibility is hypothesised to have been weaker than in fully aquatic species, enabling evolution of more strongly synchronised life histories with the potential to maximise mating success.

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